MR Imaging of the Hip

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Introduction

Indication for MR imaging of the hip

- AVN
- Occult Fractures
- Labral Tear
- Tumors
  - benign and malignant
  - detect and characterize
- Soft tissue injury
  - tendon tear, muscle strain, hematoma
- Arthritis
- Hip pain with negative conventional radiograph

Advantages of MRI

- Superior soft tissue contrast
- Multiplanar Imaging
- No iodinated contrast
- No exposure to radiation
- Sensitive, accurate & cost effective
- Provides comprehensive exam

Normal Anatomy of Hip Joint

- Synovial lined ball-and-socket joint
  - Femoral head constrained within relatively deep acetabulum
  - Designed to maintain stability while transmitting large forces
  - Peri-articular soft tissue structures contribute to stability
    --capsule, ligaments, labrum, muscles & tendons
- Articular Cartilage
  - horseshoe-shaped cartilage lines acetabulum
  - cartilage-devoid region of acetabulum medially → fossa
  - acetabular fossa covered by fibrofatty tissue, synovium and ligamentum teres
  - cartilage is thin (~3mm in thickness)
  - femoral head covered with cartilage (except @ fovea)
- Acetabular Labrum
  - attached to the rim of the acetabulum
  - deepens acetabulum and provides additional coverage of femoral head
  - comprised of fibrocartilage, triangular in cross section
  - ↑ thickness posterosuperiorly & thinner anteroinferiorly

- Joint Capsule
  - extends from margin of acetabular rim to base of femoral neck
  - proximal femoral physis is intracapsular and trochanters are extra-capsular
  - inserts to acetabular rim @ base of labrum
    --creates peri-labral recess
  - extrinsic ligaments (external to fibrous capsule)
    --reinforce the joint
    --pubofemoral, iliofemoral & ischiofemoral ligaments
    --zona orbicularis encircles capsule @ base of neck

- iliofemoral ligament restricts extension and posterior displacement of hip
- ischiofemoral ligament stabilizes the hip in flexion and adduction
- pubofemoral ligament restricts hip abduction
- iliopsoas tendon & bursa
  --intimately associated with anterior aspect of hip joint
  --direct communication between joint & bursa in 10-15% of the population
  --hiatus between the iliofemoral and pubofemoral ligaments

- Ligamentum teres
  - extends from acetabular notch to fovea capitus of femoral head
  - carries artery of the ligamentum teres (supplies blood to femoral head in children)
  - may serve as transarticular route for spread of tumor

MR Imaging Protocols

- Vary with indication and equipment
- General protocol categories
  - routine "screening" hip (R/O AVN, non-specific hip pain)
  - dedicated unilateral hip (internal derangement, lesion characterization)
  - MR arthrography (intra-articular gadolinium)
- Surface or phased array torso coil

Routine "Screening" Hip MRI Protocol		
Parameter	Sequence/Weighting	
	SE T1	FSE-XL T2
Imaging Plane	Axial	Axial
	Coronal	Coronal
TR (ms)	500-600	3000-4000
TE (ms)	minimum full	90
NEX	2	2
Matrix	256 x 256	256 x 256
FOV (cm)	38 or to fit	38 or to fit
Thickness/gap (mm)	7/3 (axial), 5/2.5 (coronal)	7/3 (axial), 5/2.5 (coronal)
Fat Saturation	no	yes

Unilateral Hip MRI Protocol		
Parameter	Sequence/Weighting	
	FSE-XL T2	FSE-XL T1
Imaging Plane	Axial	Axial
	Coronal	Coronal
	Sagittal	
TR (ms)	3500	600
TE (ms)	45	minimum full
NEX	2	2
Matrix	256 x 256 (axial) 256 x 224 (cor & sag)	256 x 256
FOV (cm)	22 (axial), 24 (cor & sag)	22 (axial), 24 (coronal)
Thickness/gap (mm)	6/2 (axial), 5/1 (cor & sag)	6/2 (axial), 5/1 (coronal)
Fat Saturation/TRF/zip512	yes	no

MR Arthrography (2 step procedure)

1. Intra-articular gadolinium injection
   - Fluoroscopic guidance; use sterile technique & local anesthesia
   - Access joint with 22 g spinal needle
   - Document intra-articular position with 2-3 cc's iodinated contrast
   - Inject diluted gadolinium solution
     – 10-15 cc's (titrate to patient)
     – 1:200 Gadolinium: normal saline dilution (0.1 cc Gad: 20 cc's NS)
2. MR Arthrography Imaging Protocol

Post Gadolinium HIP MRI Protocol			
Parameter	Sequence/Weighting		
	FSE-XL T1	FSE-XL T2	FSE-XL T1
Imaging Plane	Axial	Axial	Coronal
	Coronal or oblique coronal	Sagittal	
	Sagittal or oblique Sagittal		
TR (ms)	600-650	4000	500-600
TE (ms)	minimum full	40-45	minimum full
NEX	2	2	2
Matrix	256 x 224	256 x 256	256 x 224
FOV (cm)	16	16	16
Thickness/gap (mm)	3/0.5	3/0.5	3/0.5
Fat Saturation/TFF/zip512	yes	yes	no

HIP PATHOLOGY

Labral Tears

- ↑'d attention in orthopedic & radiology literature over past decade
- Increasingly recognized as a cause of hip pain
- Patients present with inguinal pain, painful clicking, transient locking or giving way
- Pain with flexion, adduction & internal rotation
- Common etiologies
  – OA, DDH, Perthes, Trauma
- Less common etiologies
  – Subtle structural abnormalities
  – Femoroacetabular impingement

Femoroacetabular Impingement

- Pathogenic factor in development of "idiopathic" osteoarthritis of the hip
- Clinical characteristics
  – painful internal rotation of hip
  – positive impingement test (pain @ 90° flexion, adduction and internal rotation)
- Etiology
  – reduced concavity of anterior femoral head-neck junction or prominent acetabular rim
  – abnormal contact between neck & anterosuperior acetabular rim
  – associated with labral tears & cartilage defects
- Two major types
  – CAM & Pincer

- Conventional radiographic findings
  – decrease in femoral head-neck offset
  – retroversion of the acetabulum
  – osteophytic or cystic changes in region of anterosuperior femoral neck
  – cystic change & sclerosis in the roof of the acetabulum
- MR imaging findings
  – labral tear (usually anterosuperior)
  – chondromalacia
  – subchondral degenerative change & edema
    --femoral head-neck junction
    --roof of acetabulum
- Treatment options
  – periacetabular osteotomy
  – femoral head-neck re-contouring procedure
  – proximal femoral osteotomy

- Diagnosis
  –combination of radiograph & MRI
  –Many structural abnormalities can be identified on conventional radiographs
  –familiarity with structural abnormalities on radiography is critical
    --early detection
    --accurate diagnosis
    --optimize treatment plan & prognosis
    --prevent or delay pain & disability

Normal Acetabular Labrum

- Homogeneous low signal intensity
- Triangular morphology
- Continuous attachment between labrum and acetabulum
- Peri-labral recess between labrum and joint capsule

Abnormal Acetabular Labrum

- Labral degeneration
  – abnormal signal intensity within substance of labrum
- Labral tear
  – round, blunted or flattened morphology
  – intra-substance contrast material or abnormal signal extending to labral margin
  – most commonly occur in anterosuperior quadrant of the labrum
- Labral detachment
  – displaced or non-displaced
  – abnormal signal or contrast insinuation between labrum and acetabulum
- Labral thickening
  – loss of normal recess between labrum and joint capsule

Injuries Associated with Labral Tear or Detachment

- Chondral defects
  – occur in up to 30% of patients with labral lesion
- Para-labral Cyst
  – may be seen with labral tear, especially with labral detachment
  – ↑ prevalence in OA, DDH & post-traumatic injury

– juxta-articular, usually superolateral or anterosuperior
– may or may not fill with gadolinium @ time of MR arthrography
– identification of cyst → should raise clinical suspicion of underlying labral tear

Staging of Acetabular Labral Lesions (see Figure 1)

- Stage 0
  – homogenous low signal intensity with triangular morphology
  – normal acetabular – labral interface and peri-labral recess
- Stage 1 A
  – presence of intra-labral signal which does not extend to labral margin
- Stage 2 A
  – presence of intra-substance contrast material extending to labral margin
- Stage 3 A
  – displaced or non-displaced labral detachment from acetabulum
- Stages 1 through 3, Type B – as described in Type A 1-3 with addition of hypertrophy of labrum
  – obliteration of peri-labral recess

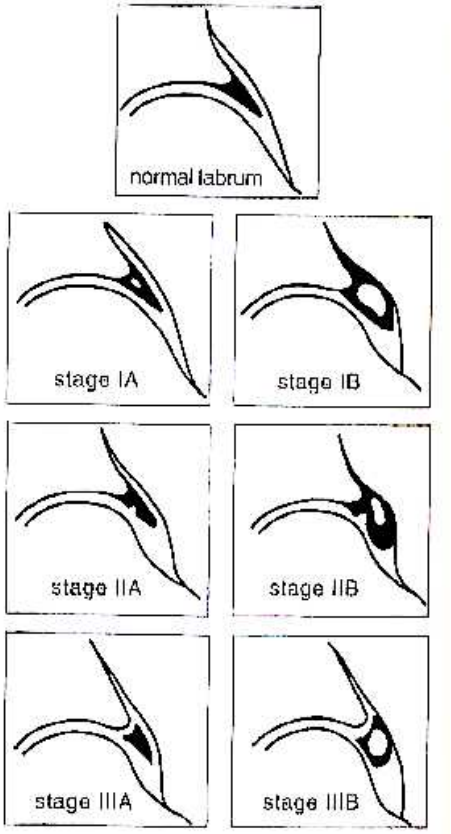

Figure One: Schematic diagram illustrating the classification system used to stage labral abnormalities (Czerny et al, Radiology 1996; 200:225-230)

Accuracy of MRI for Diagnosis of Acetabular Labral Tear

- MR arthrography
  – 90 % sensitivity
  – 91 % accuracy
- Conventional MR imaging
  – 30 % sensitivity
  – 36 % accuracy

Advantages of MR Arthrography

- Accurate anatomic delineation of labral anatomy and pathology
- Increased sensitivity for detection of labral pathology
  – contrast dissects into labrum or between labrum and acetabulum
  – ↑ conspicuity labral tear and/or detachment
- Comprehensive evaluation of bones & soft tissues within and about the joint

Osteonecrosis

- Femoral head is the most common site
- Pathogenesis → vascular compromise
  – intra-osseous hypertension with vascular stasis
  – thromboembolic abnormalities
  – traumatic disruption of blood vessels
- Risk Factors
  – corticosteroids
  – alcoholism
  – pancreatitis
  – hemoglobinopathies (sickle cell disease)
  – collagen vascular disease
  – trauma
  – barotrauma

MR Imaging of AVN

- Sensitivity, specificity & accuracy of MRI for diagnosis of AVN is > in 90%
- MRI is more sensitive than CT or nuclear scintigraphy
- MRI is 97% sensitive and 98% specific in differentiating AVN from other pathology
- MRI also effective for evaluating for associated joint effusion & marrow edema
  -edema may extend to intertrochanteric region (especially with Stage III)
  -joint effusions are variable in size (larger in Stage III and IV)
- Imaging features vary with stage and extent of disease
- Focal subchondral signal abnormality on T1 and T2 weighted images
  -crescentic, round, band-like focus of abnormal subchondral signal
  -may be demarcated by a serpiginous margin

- "Double Line Sign"
  – pathognomonic for AVN
  – concentric bands of low & high SI on T2 weighted images
  – reactive granulation tissue at interface between necrotic & normal bone

Transient Bone Marrow Edema

- Also known as transient osteoporosis
- Self-limited disorder, gradual onset of pain over weeks to months
- May be regional and migratory
- Gradual onset of pain over weeks to months
- Typical affects patients in the 20-50 year age range
- Male to female ratio 3:1
- Hip is the most common joint involved

Imaging features of Transient Bone Marrow Edema

- Radiographs shows regional osteopenia of femoral head and neck
- No erosions or joint space narrowing
- MRI is the imaging modality of choice
  – highly sensitive and specific
- MR imaging findings
  – ill-defined region of signal abnormality with low T1 & high T2 signal
  – involves femoral head & neck from joint surface to intertrochanteric region
  – absence of focal subchondral defect to indicate etiology due to AVN or fracture
  – signal abnormality resolves over 3-6 months if followed with sequential MRI

Fractures

- MRI sensitive & specific for occult fracture detection
  – stress fractures
  – non-displaced traumatic fractures (e.g. femoral neck)
- Accurate diagnosis can be difficult on radiographs
  – especially elderly osteoporotic patients
- Early and accurate diagnosis is critical for prompt and appropriate treatment
- MRI is imaging modality of choice
  – patients with high clinical suspicion of fracture & negative radiograph
- Spectrum of fractures detected on MRI with negative x-ray
  – femoral neck fractures
  – intertrochanteric fractures
  – stress fractures
  – subchondral insufficiency fracture of the femoral head
  – extra-articular sites
    --pubic rami
    --sacrum
    --supra-acetabular ilium
- **Stress Fractures**
  – fatigue
    --abnormal stress applied to normal bone
  – insufficiency
    --normal stress applied to abnormally weakened bone
- Etiology of insufficiency fractures
  – osteoporosis
  – RA
  – osteomalacia
  – renal osteodystrophy
  – radiation
- MR imaging of insufficiency type stress fractures
  – comparable sensitivity & superior specificity to nuclear scintigraphy
  – T1 weighted images
    --linear focus of low SI
    --surrounded by larger ill-defined region of hazy or reticulated ↓ in SI

– T2 weighted images
--linear focus of low SI
--surrounded by larger region of high SI
--signal abnormality >>'r than on T1
--↑ sensitivity for detection with fat suppression techniques
– frequently associated with soft tissue edema

- **Subchondral insufficiency fracture of femoral head**
  – typically seen in osteoporotic women
  – acute onset of pain
  – no risk factors for AVN
  – MR imaging
  --bone marrow edema which may extend to intertrochanteric region
  --transverse linear focus of low SI in subchondral region of femoral head
  – may progress to subchondral collapse

Arthropathies

- Differential diagnosis for arthritides of the hip joint
  – osteoarthritis
  – inflammatory arthritis
  – septic arthritis
  – other (PVNS, synovial chondromatosis)
- MRI is not usually required for diagnosis. Correlation with radiographs is critical.

Septic Arthritis

- More common in children than adults
- Risk factors
  – septicemia
  – previous joint injection
  – immunocompromised status
- Radiographs
  – may be negative
  – osteopenia
  – periarticular soft tissue swelling
  – ± erosions & joint space narrowing
- MR imaging features
  – joint effusion & synovitis
  – ± erosions & joint space narrowing
  – late stage may reveal extra-articular extension
  --periarticular soft tissue edema
  --soft tissue abscess
  --osteomyelitis

Pigmented Villonodular Synovitis

- Benign proliferative synovial process
- Involves joint, bursa or tendon sheath
- Typically affects young to middle-age adults
- Anatomic sites of predilection
  – knee (80%), hip, ankle, shoulder
- Conventional Radiography
  – hyperdense joint effusion
  – preservation of joint space & bone density, ± bone erosions

- MR Imaging Features
  – joint effusion with nodular synovial thickening
  – nodular masses with low SI on T1 & T2 weighted images

--due to hemosiderin deposition
– low SI nodules typically surrounded by high SI fluid on T2 weighted images
– ± blooming on gradient echo image acquisition
– differential diagnosis
--synovial chondromatosis
--chronic proliferative synovitis
--hemophilic arthropathy

Synovial Chondromatosis

- Cartilage metaplasia in synovium
- Monoarticular disease, M:FM ratio 2:1, peak incidence 3rd-5th decade
- Skeletal distribution
  – knee (50%), hip, elbow, shoulder, ankle
- Conventional radiography
  – multiple, calcified intra-articular loose bodies of fairly uniform size
  – 70-75% show calcification on x-ray
  – preservation of joint space & normal bone density
- MR Imaging features
  – joint effusion (high SI on T2 weighted images)
  – multiple tiny round low signal intensity nodules of uniform size
  – low SI on T1 & T2
  --low T2 signal reflects calcification/mineralization
  – ± bone erosions
  – differential diagnosis on x-ray
  --osteoarthritis
  --trauma
  --osteochondritis dissecans
  --neuropathic joint disease
  – differential diagnosis on MRI
  --PVNS
  --rheumatoid arthritis
  --chronic proliferative synovitis

Miscellaneous Pathology-Diagnostic dilemmas & tumor simulators

- Occult neoplasms (e.g. lymphoma)
- Osteoid osteoma
- Calcific tendonitis
- Myositis ossificans

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